

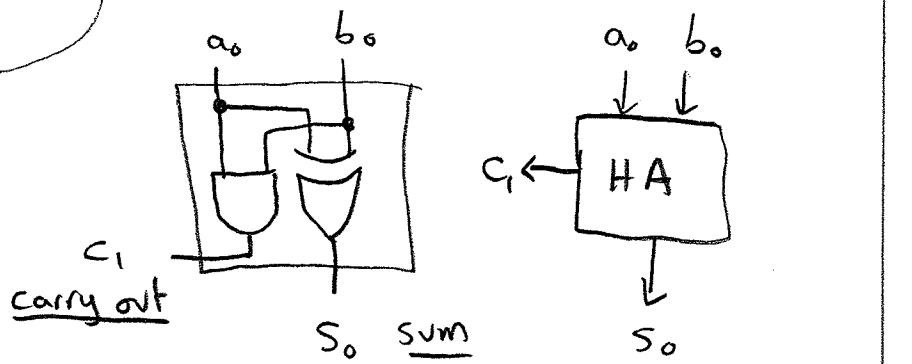
## Arithmetic using Logic

Half  
Adder

$$\begin{array}{r} +1 \\ \hline 10 \end{array} \quad \begin{array}{c} a_0 \\ + b_0 \\ \hline c_1 \text{ } s_0 \end{array}$$

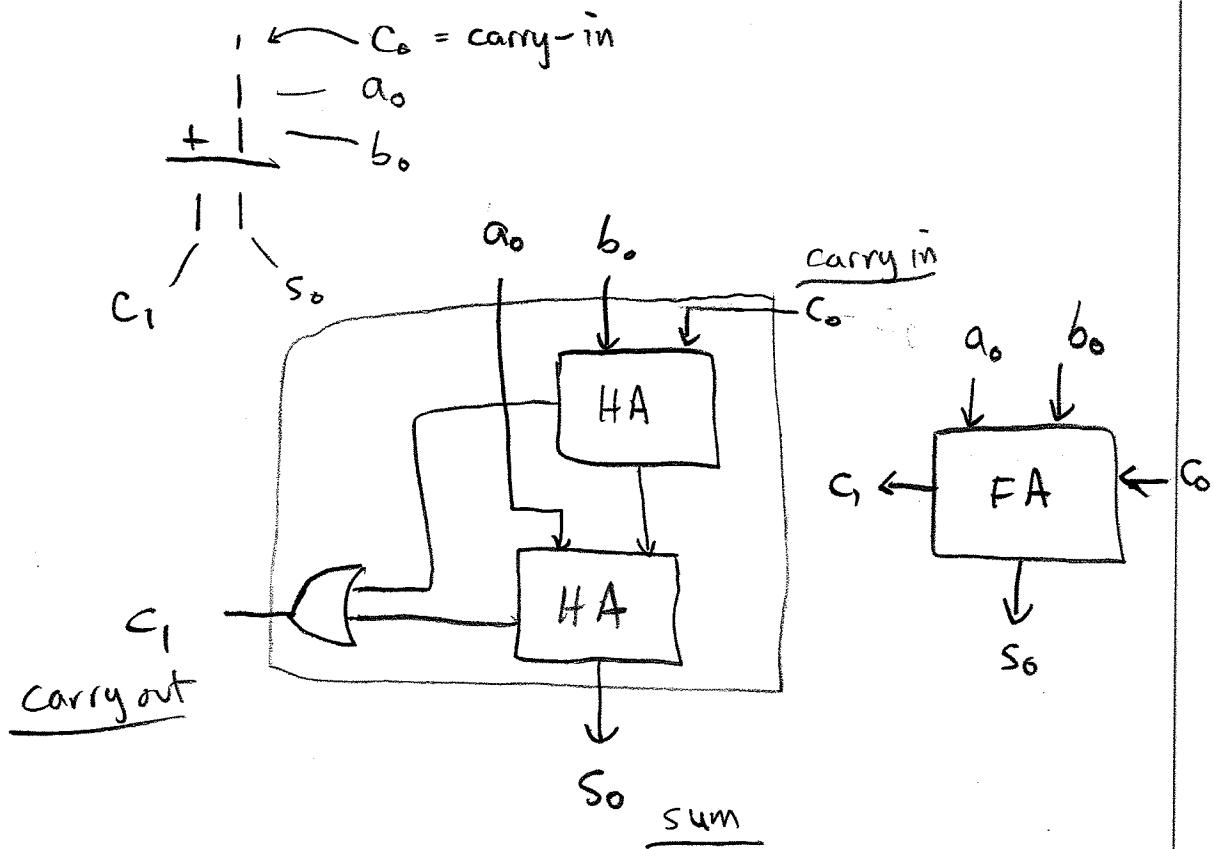
$$s_0 = a_0 \oplus b_0$$

$$c_1 = a_0 \cdot b_0$$

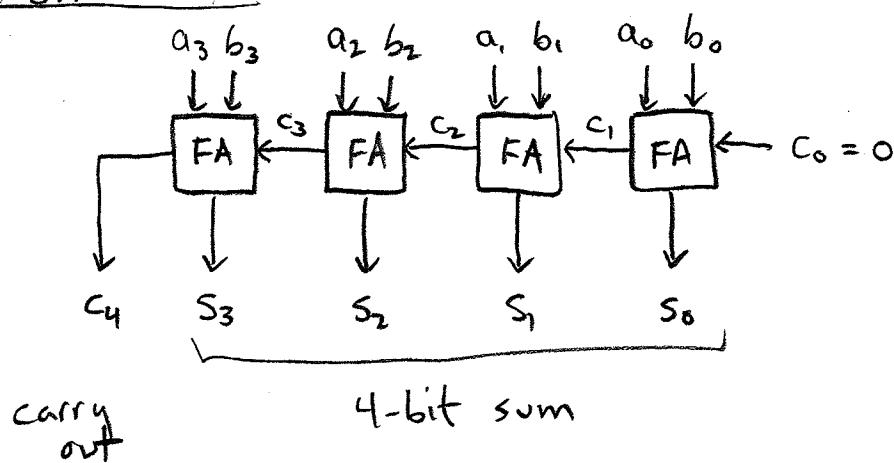


Full  
Adder

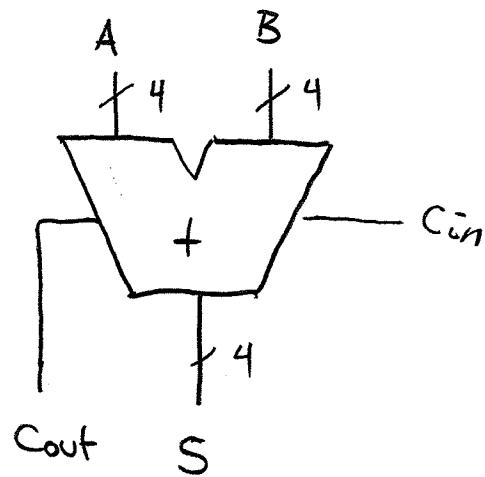
$$= 2 \times \text{Half Adders} + 5$$



Verify: logic for carry-out  $c_1$  is correct

4-bit adder

also:

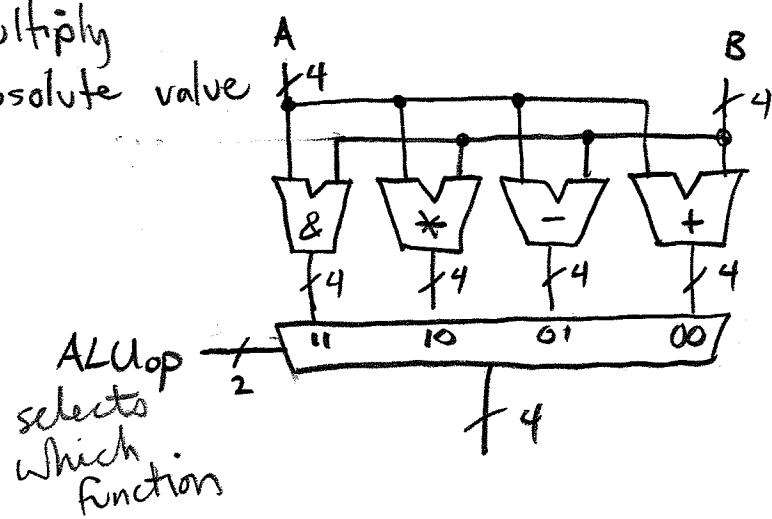
ALU : arithmetic logic unit operates on integers

common operations

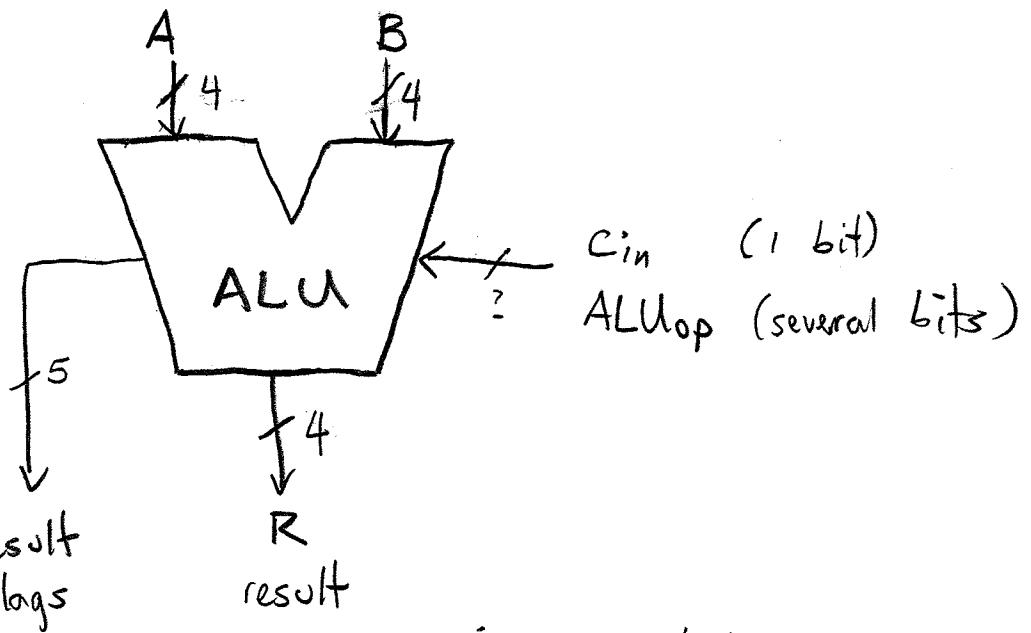
- add, subtract
- bitwise AND, OR, XOR
- shift
- multiply
- absolute value

eg, bitwise AND:  
 $\begin{array}{r|rrrr} & a_3 & a_2 & a_1 & a_0 \\ \& b_3 & b_2 & b_1 & b_0 \\ \hline & a_3 b_3 & a_2 b_2 & a_1 b_1 & a_0 b_0 \end{array}$

easy way to build

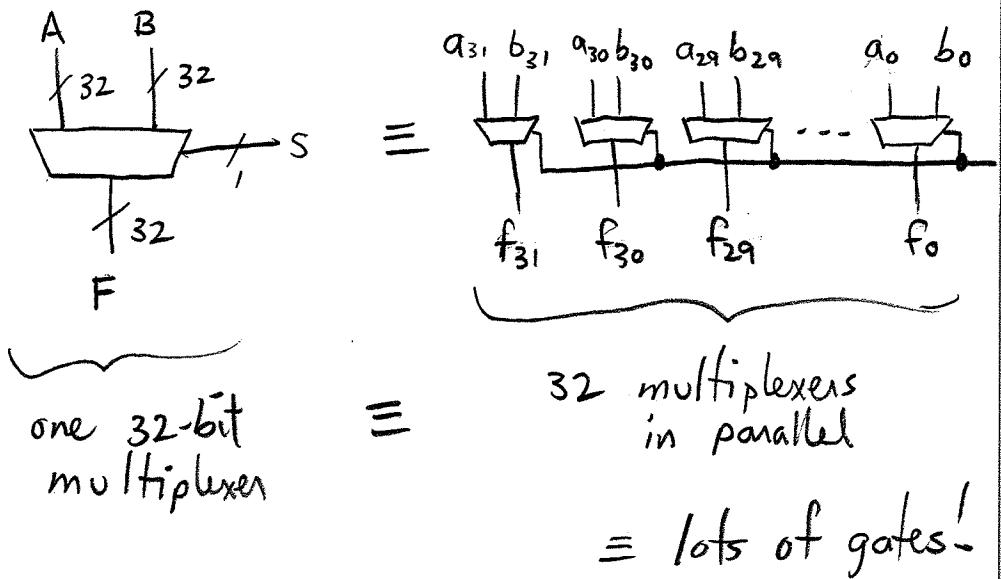


Symbol

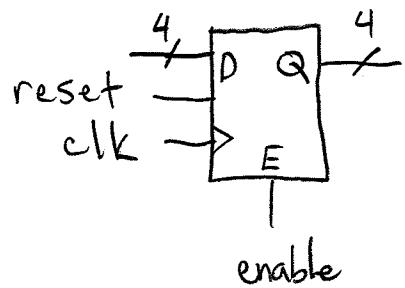


- { 1 bit each
- C carry out ( $C=1$  if addition results in carry)
  - B borrow ( $B=1$  if subtraction requires a borrow)
  - V overflow ( $V=1$  if ALUop results in overflow)
  - N negative ( $N=1$  if MSB of  $R=1$ )
  - Z zero ( $Z=1$  if all bits in  $R=0$ )

Note:



Registers a group of DFFEs with common clock and enable signals



reset clears all DFFEs (to 0)

preset sets all DFFEs (to 1)  
immediately, no clock or enable needed

Accumulator

- type of an adder/counter
- has memory (register)

